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UNIFILTER COLLECTING SYSTEM FOR COTTON-GIN WASTE MATERIALS

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CONTENTS

	Page
Abstract	1
Introduction	1
Preliminary investigation of unifilter	2
Prototype of unifilter collecting system	3
Design	3
Operation	3
Experimental procedure	4
Results and analysis	6
Unifilter for commercial gin systems	7
Design	7
Design modifications	8
Size selection	9
Conclusions	9
Acknowledgments	9

ILLUSTRATIONS

Fig.		
1.	Component arrangement of prototype unifilter	3
2.	Vacuum nozzles for doffing filter drum	3
3.	Prototype of unifilter	3
4.	Variable-speed fan on sampling duct	4
5.	Sampling location on air discharge of filter unit	4
6.	Sampling nozzles and high-volume air samplers	5
7.	Control station for monitoring high-volume air samplers	5
8.	Commercial-size experimental trash-collecting system	7

TABLES

1.	Results of using foam-filter medium with prototype unifilter	6
2.	Results of using mesh-screen filter medium with prototype unifilter	7
3.	Data for selecting proper size unifilter for commercial ginning systems	8

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
in cooperation with
Mississippi Agricultural and Forestry Experiment Station

UNIFILTER COLLECTING SYSTEM FOR COTTON-GIN WASTE MATERIALS

By O. L. McCaskill and R. A. Wesley[1]

ABSTRACT

A totally new experimental trash-collecting system for collecting all waste from cotton gins was designed, constructed, tested, and evaluated. This system consists of an enclosure containing revolving filter drums, doffing vacuum nozzles, impinging baffles, sloping trash hopper, and screw conveyor and fan for removing trash. With a polyurethane-foam filter medium, this collecting system operated at an average collection efficiency of 99.38 percent. This performance level is comparable to, or slightly higher than, currently available abatement equipment. This experimental collecting system performed satisfactorily for 2 years under field conditions during the processing of approximately 12,000 bales of cotton and is currently being produced by cotton-gin equipment manufacturers for collecting all cotton-gin waste materials. Modified versions of the system are also being produced for collecting the lighter materials emitted from cotton condenser systems. **KEYWORDS: air-pollution abatement, cotton-gin air-filter equipment, cotton-gin waste collection.**

INTRODUCTION

Researchers in the U.S. Department of Agriculture try to anticipate the future needs of the cotton-ginning industry. Currently, one of the most pressing needs, since passage of the Federal Clear Air Act of 1963, is for air-pollution abatement equipment for waste collection and disposal.

Most cotton gins emit only one type of pollutant into the atmosphere, a particulate matter that discharges directly into the atmosphere or escapes from some type of abatement equipment. At the present time all cotton-producing States are operating under some form of process-weight standard having an allowable emission level based on the total weight of the material being processed.

The actual emission levels from gins vary somewhat and depend to a large degree on the time and method of harvest. During the 1974–75 cotton-harvesting season 79 percent of the crop was machine picked, 20 percent machine stripped, and 1 percent handpicked.[2] The amount of foreign matter removed by gin equipment is quite variable. Data indicate that the amount removed varies from an average low of 107 pounds per bale for handpicked cotton to 200 pounds per bale for spindle-picked cotton to an average high of 840 pounds per bale for machine-stripped cotton.

The conveying systems in modern cotton gins are predominantly pneumatic and require large volumes of air to move cotton through the processing sequence. A gin with a capacity of 12 to 15 bales per hour requires approximately 100,000 cubic feet of air per minute to operate properly. The trash removed from seed cotton by the cleaning equipment is usually trans-

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[2] Charges for ginning cotton, costs of selected services incident to marketing, and related information, season 1974–75. 1975. U.S. Dep. Agric., Econ. Res. Serv. [Rep.] ERS–2, 2 pp.

ported from the gin by these pneumatic systems.

The following three primary methods of collection and abatement are in use today: (1) High efficiency cyclones on the high-pressure fan discharges, (2) inline filters on the low-pressure fan discharges, and (3) fine-screen covering on condenser drums in the low-pressure systems. The cyclones are the most widely used collection equipment on the high-pressure discharges, and they collect the bulk of the waste being discharged. The proper size high-efficiency cyclone, based on the volume of air entering the cyclone, collects 99.9 percent of the total trash introduced and virtually 100 percent of the trash particles larger than 30 micrometers in diameter.[3] Inline filters are used on the low-pressure discharges from lint-condenser systems to collect lint fly and dust. Inline filters are of either the stationary-screen or revolving-drum design. This equipment, when properly sized and operated, has an overall collection efficiency of approximately 80 percent.[4] Lint fly from condenser exhausts can also be controlled by using finely woven screen wire to cover the standard condenser drum or by replacing the standard drum covering with perforated metal having openings smaller than those of the standard covering. This method is less expensive than using the inline filters, and it has an efficiency of approximately 50 percent.[5]

This report presents the design, operation, test procedures, and evaluation of test results for a new waste-filtering unit designed to collect all waste materials from cotton gins.

PRELIMINARY INVESTIGATION OF UNIFILTER

The unifilter, a totally new concept for collecting all waste from cotton gins, was designed to replace all cyclones, inline filters, and covered condenser drums with a collecting unit that would operate more efficiently than the present abatement equipment. This experimental trash-collecting system was developed over a 5-year period (1969–74) at the U.S. Cotton Ginning Research Laboratory in Stoneville, Miss.

In 1969 the possibilities of collecting particulate matter from a cotton gin by using a trash trap with a fine-screen filter were investigated. The system was designed as an enclosure consisting of an air inlet, deflecting baffle, stationary 100- by 100-mesh screen filter, cleaning brush, and air outlet. As trash-laden air entered the enclosure, the baffle deflected the heavier material downward to the collecting chamber, and the lighter materials remained in the airstream and were transported to the screen filter for collection. Problems were encountered with this design. The heavier material was collected as expected; however, excessive quantities of lint fly and fine-leaf trash collected on the filter screen so rapidly that the brush could not sweep the filter clean, which caused excessive back pressure on the ginning system.

A second test in 1969 involved a filter enclosure containing a revolving cylindrical drum covered with a polyurethane-foam filter medium. The cylindrical drum, similar to a conventional lint-cleaner condenser drum, contained 60 square feet of filter surface area. The foam filter was capable of handling 15,000 cubic feet of air per minute at a face velocity of 250 feet per minute.[6] As trash from the lint-cleaner condenser entered the enclosure, the material was collected by the revolving drum and was efficiently doffed from the drum by vacuum nozzles.

Research in 1970 resulted in a filter enclosure that incorporated the desirable features of the two previous research efforts. This unit consisted of a cylindrical drum with 120 square feet of filter-surface area covered with polyurethane foam. Stationary vacuum nozzles efficiently doffed the collected material from the revolving drum. The backwash effect of the nozzles on the foam filter increased the collection efficiency of the unit and held the static pressure of the system to less than 0.5 inch water gage. These operational tests indicated

[3] Wesley, R. A., Mayfield, W. D., and McCaskill, O. L. 1972. An evaluation of the cyclone collector for cotton gins. U.S. Dep. Agric. Tech. Bull. No. 1439, 13 pp.

[4] Baker, Roy, and Parnell, Calvin B., Jr. 1971. Three types of condenser filters for fly lint and dust control at cotton gins. U.S. Dep. Agric., Agric. Res. Serv. [Rep.] ARS 42–192, 13 pp.

[5] McCaskill, O. L., and Moore, V. P. Elimination of lint fly. The Cotton Gin and Oil Mill Press, Dec. 31, 1966, pp. 5–7.

[6] Face velocity is the velocity of the air as it enters the surface of the filtering medium.

that this filter system could possibly be adaptable for total trash collection at cotton gins.

PROTOTYPE OF UNIFILTER COLLECTING SYSTEM

Design

The experimental trash-collecting system developed in 1971–72 was composed of a settling chamber equipped with an impinging baffle and a drum covered with 80/45 polyurethane foam. Figure 1 shows the arrangement of the various components of the system. The filter drum was 5 feet in diameter and 10 feet long, and it had approximately 120 square feet of filter-surface area. The light material that collected on the filter was doffed by four vacuum nozzles (fig. 2). Each nozzle required approximately 700 cubic feet of air per minute for proper operation.

The filter enclosure was 12 feet long, 10 feet wide, and 10 feet high, and it was equipped with a trash hopper and trash fan for removing the heavy trash concurrently with ginning. The condenser air entered at the top of the enclosure and was diverted by a baffle to prevent the air from blowing directly on the filter drum. The trash lines entered the enclosure below the centerline of the drum. The trash-laden, high-velocity air struck a baffle that deflected the heavy trash down into the trash hopper, thus protecting the filter from direct contact with heavy trash. An auger at the bottom of the hopper moved the heavy trash to a No. 30 fan that delivered it to a cyclone, where it was collected for weighing. The slope of the hopper walls was 45° on the trash-inlet side, 75° on the opposite side, and 90° on each end (fig. 3).

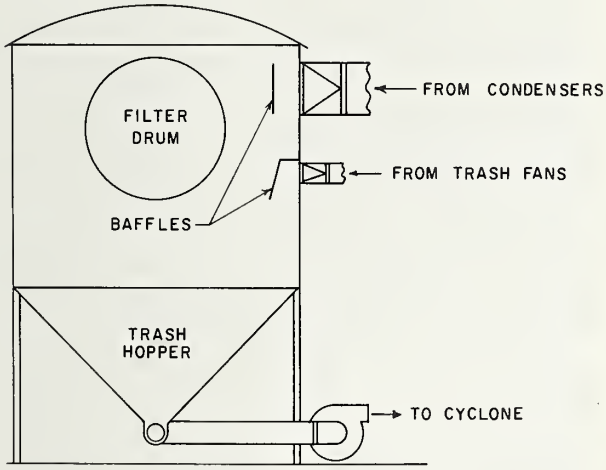

FIGURE 1.—Component arrangement of prototype unifilter.

Operation

The experimental trash-collecting system (fig. 3) was observed and evaluated while it was operating concurrently with ginning.

The following air systems were introduced into the filter enclosure: (1) The No. 1 drying system that handles trash from a six-cylinder cleaner and stick machine, (2) a trash fan that handles trash from the lint cleaners, ex-

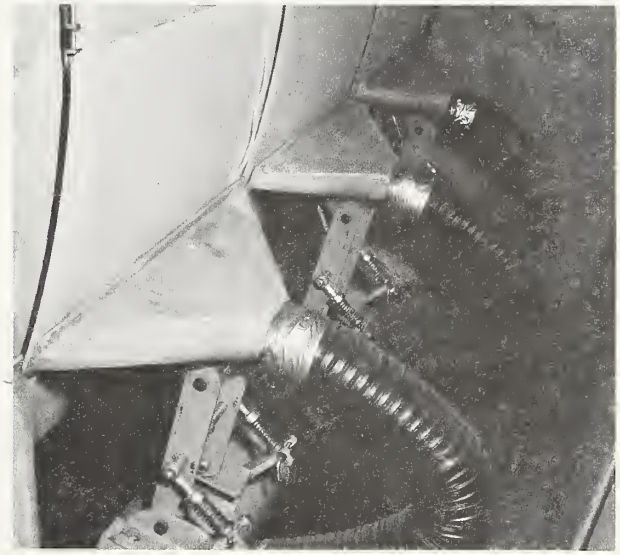

FIGURE 2.—Vacuum nozzles for doffing filter drum.

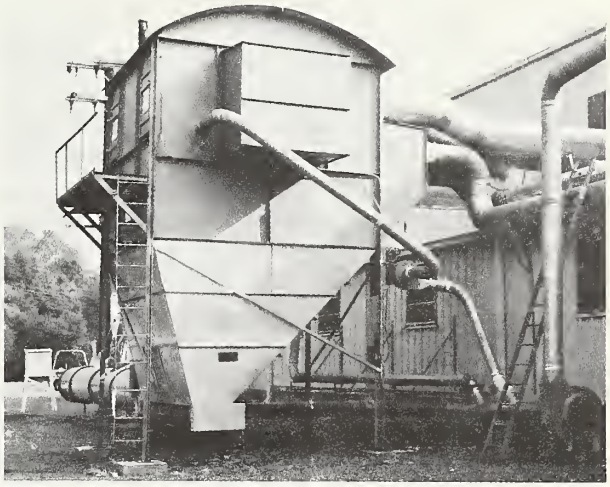

FIGURE 3.—Prototype of unifilter.

tractor feeders, and gin-stand huller fronts, and (3) two unit-lint-cleaner condenser exhausts. The air volume to the enclosure was held constant, and the input air volume averaged 23,267 cubic feet per minute, with 4,062 cubic feet per minute being removed from the enclosure by the vacuum nozzles and trash fan. The vacuum nozzles had inlet openings 0.88 by 24 inches. The remaining 19,205 cubic feet per minute passed through the filter at a face velocity of 153 feet per minute and into the atmosphere.

Two types of filter media were evaluated in these tests. In addition to the 80/45 polyurethane foam, a 70- by 70-mesh stainless-steel screen (with an open area of 54.9 percent) was tested. The average static pressure in the filter chamber was 0.46 inch water gage for the foam and 0.15 inch water gage for the screen. A definite horsepower savings results from the low static pressure of the unifilter system. High-efficiency cyclones operate at a static pressure of approximately 5 inches water gage, and inline filters operate at ½ to 1 inch static pressure.

No operational problems were encountered with the foam. However, with the screen a problem existed in doffing with the vacuum nozzles. As the screen rotated, the surface of the screen did not have enough frictional resistance to pull the trash under the nozzles. Thus, the trash piled up in front of the nozzles and eventually choked them.

Experimental Procedure

The investigation was designed for seed-cotton ginning rates of four, six, and eight bales per hour, which created various trash-input levels to the filter enclosure. The experiment was run as a randomized complete-block design. The procedure involving the foam filter was replicated four times with early-season machine-picked cotton, and the experiment with the screen filter was replicated three times with cotton harvested later in the season.

In order to sample the exhaust air from the filter isokinetically, it was necessary to bring all the air from the filter through a variable-speed vaneaxial fan to the sampling location, which was 8 pipe diameters downstream and 2 diameters upstream from any flow disturbance (figs. 4 and 5). The variable-speed vaneaxial fan was used to establish a zero static pressure at the point where the filter normally discharges into the atmosphere.

Two sampling nozzles (fig. 6) were used to sample across the diameter of the 36-inch duct.

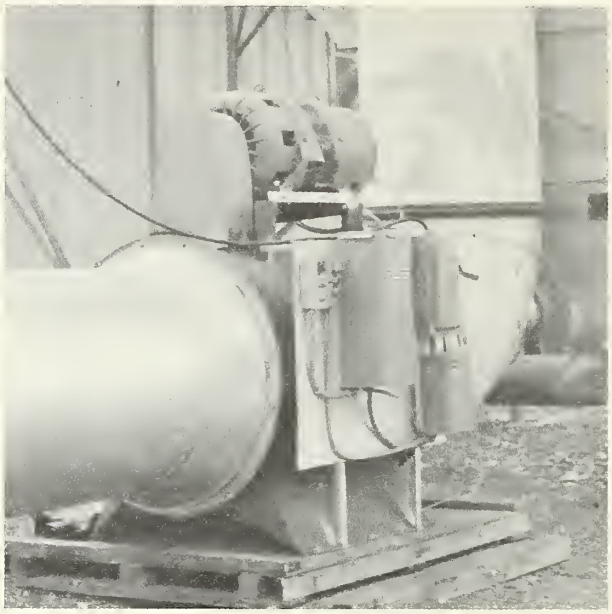

FIGURE 4.—Variable-speed fan on sampling duct.

FIGURE 5.—Sampling location on air discharge of filter unit.

These movable nozzles, operating simultaneously, traversed the duct at right angles to each other. The sampling traverse consisted of two sets of readings 90° apart, with each set composed of six traverse points (according to the Federal Register, vol. 36, No. 247, Pt. II). Each 1½-inch-diameter sampling nozzle was equipped with a ⅛-inch-diameter pitot tube positioned 5 inches in front of the nozzle inlet. This pitot tube was used to monitor the velocity of the air in the 36-in-diameter duct. Another ⅛-inch pitot tube, placed inside each sampling tube, was located 10 diameters downstream and 2 diameters upstream from any flow disturbance. This pitot tube was used to monitor the velocity of the air being sampled by the high-volume air samplers.

Two high-volume air samplers, equipped with special inlet transitions (fig. 6), were used to sample the exhaust air. A Gelman type-A glass-fiber filter was used on the high-volume air sampler to collect the particulate matter from the sampled air. The intake air volume of the high-volume samplers was controlled with a variable-voltage transformer in order to establish and maintain isokinetic sampling at each point of the traverse. The sampling time at each traverse point was 4 minutes at a sampling-volume ratio of approximately 1 to 250 cubic feet per minute. Figure 7 shows the control station, which consisted of four inclined manometers and two variable-voltage transformers for obtaining isokinetic sampling conditions.

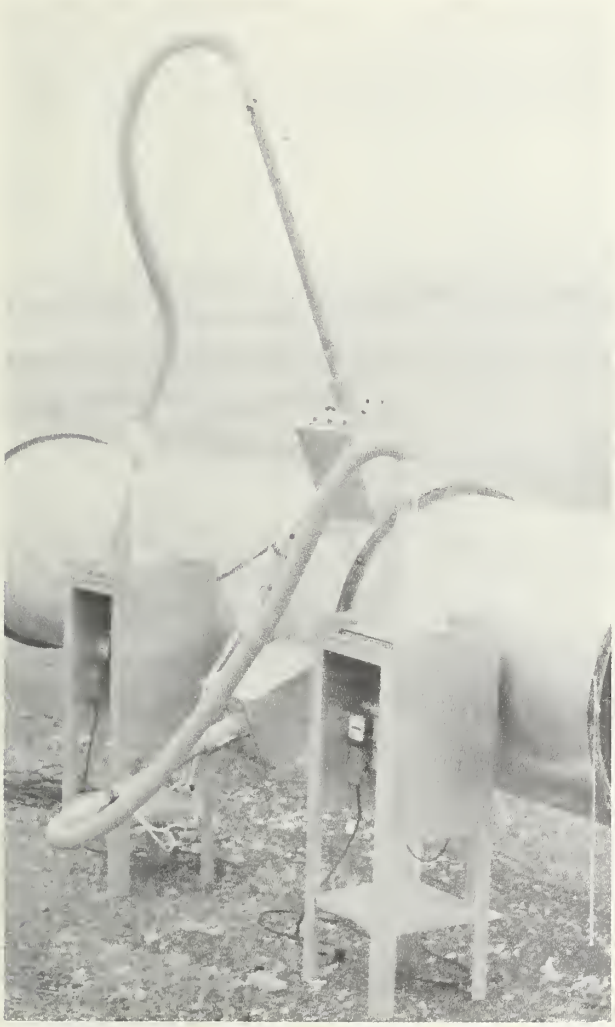

FIGURE 6.—Sampling nozzles and high-volume air samplers.

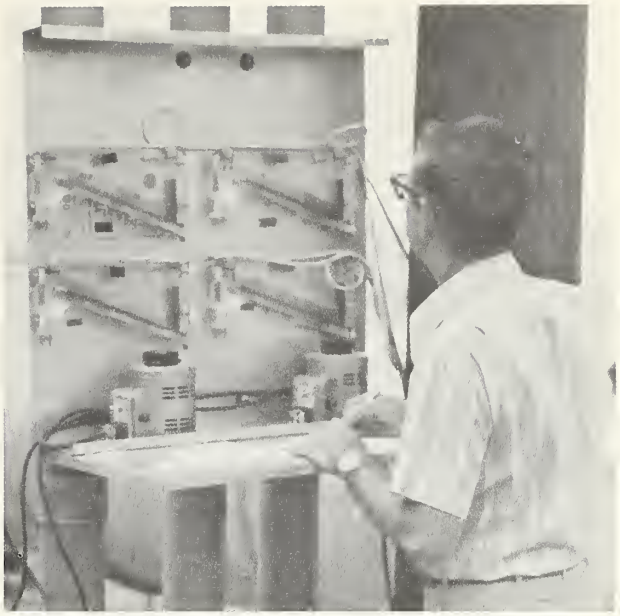

FIGURE 7.—Control station for monitoring high-volume air samplers.

Accurate records were maintained on the quantity of material that entered and that was collected by the experimental unit. This material was conveyed to a cyclone collector, where the material was collected and weighed for each test lot. Samples of the particulate matter that escaped from the experimental unit were collected on the glass-fiber filters and weighed, and the quantity was expressed in micrograms per cubic meter of air handled. This dust concentration, in conjunction with the air volume handled by the experimental unit for each test lot, indicated the quantity of material that escaped from the unit. The material subjected to the experimental unit was considered to be

the sum total of the material collected at the cyclone collector and the material that escaped from the unit. The ratio of the material collected by the experimental unit to that subjected to the unit revealed the collection efficiency of the system for each test lot.

Results and Analysis

The data obtained while using the foam filter are summarized in table 1. In evaluating these data, an analysis of variance failed to reveal any significant differences in filter efficiency attributable to variations in the quantity of trash subjected to the filter. For average trash-input rates of 562, 782, and 1,175 pounds per hour, the filter-collection efficiency averaged 99.32, 99.33, and 99.49 percent. The average static pressure for the system averaged 0.46 inch water gage.

A linear regression analysis of data yielded the predicting equation $Y=99.14+0.0003X$, where Y=filter collection efficiency (percent), and X=trash input level (pounds per hour). The analysis also indicated that the regression was not significant; therefore, it must be concluded that the filter efficiency remained virtually constant for the range of trash-input rates tested. A summary of the experimental data indicated that the overall filter efficiency averaged 99.38 percent.

Data for the screen filter are summarized in table 2. An analysis of variance of filter efficiency with respect to the trash-input rate revealed significant differences in filter efficiency for the various trash-input levels. However, these conclusions are questionable because of the problems associated with doffing the screen filter. The trash piled up in front of the nozzles and eventually choked them. For average trash-input rates of 417, 619, and 728 pounds per hour, the filter efficiency averaged 96.16, 97.62, and 96.46 percent. The static pressure loss with the screen averaged 0.15 inch water gage.

A linear regression analysis of the data yielded the predicting equation $Y=95.87+$

TABLE 1.—*Results of using foam-filter medium with prototype unifilter*

Replication	Seed cotton at wagon[1]		Ginning rate (bales/h)	Total air volume[2] (stdft^3/min)	Total trash input[3] (lb/h)	Dust emission[4] (lb/h)	Filter efficiency[5] (pct)	Enclosure static pressure[6] (inH_2O)
	Moisture (pct)	Foreign matter (pct)						
1	14.0	6.4	3.76	20,212	635.46	3.97	99.37	0.47
2	9.6	5.4	4.30	18,642	565.51	5.04	99.12	.41
3	9.2	5.4	4.40	19,099	433.21	3.14	99.28	.30
4	9.3	4.9	6.90	19,287	612.87	3.11	99.49	.41
Average	10.5	5.5	4.84	19,310	561.76	3.82	99.32	.40
1	12.6	7.0	4.63	19,518	469.68	5.40	99.16	0.47
2	13.9	4.4	7.45	19,641	806.60	8.22	98.98	.53
3	12.9	7.1	8.18	20,348	978.88	4.38	99.55	.52
4	8.7	4.3	8.80	18,914	694.68	2.46	99.65	.41
Average	12.0	5.7	7.27	19,605	782.46	5.12	99.33	.48
1	10.5	6.5	7.63	18,465	1,006.39	5.93	99.41	0.51
2	14.2	5.1	9.11	19,562	1,466.32	7.76	99.47	.50
3	13.0	6.2	9.74	19,687	1,132.19	3.97	99.65	.49
4	10.9	6.1	8.51	17,922	1,095.71	6.35	99.42	.49
Average	12.2	6.0	8.75	18,909	1,175.16	6.00	99.49	.50

[1] Determined by standard moisture and fractionation tests.
[2] Air volume filtered by unit corrected to standard cubic feet.
[3] Total of material collected by filter media and particulate matter escaping unit.
[4] Particulate matter escaping unit as determined from dust concentration in micrograms per cubic meter and total air volume handled.
[5] Ratio of material collected by unit to total trash input to unit.
[6] Static pressure as measured with an inclined manometer.

0.0015X; however, the regression was not significant. Similarly, the data indicated that the filter efficiency averaged 96.75 percent for all the trash-input levels tested.

UNIFILTER FOR COMMERCIAL GIN SYSTEMS

Design

During 1973 a full-size trash-collecting system was designed, fabricated, and installed for operational studies at a commercial gin with a ginning capacity of 15 to 20 bales per hour. The enclosure was 13 feet wide, 24 feet long, and 16 feet high, and it had a trash hopper underneath (fig. 8). A 12-inch-diameter screw conveyor was located in the bottom of the hopper to convey the heavy trash to a vacuum dropper that removed the trash from the enclosure. Two filter drums, each 8 feet in diameter and 13 feet long, were located near the top of the enclosure. These drums revolved at the rate of 0.8 revolution per minute, or at the equivalent peripheral speed of 20.1 feet per minute. The filtered air was discharged from both ends of the drums to the atmosphere. The drums were covered with a nonwoven-polyester filter medium that had a higher collection efficiency than the polyurethane foam. The low-pressure condenser air entered the enclosure above the filter drums, whereas the trash-laden, high-pressure air entered below the drums and

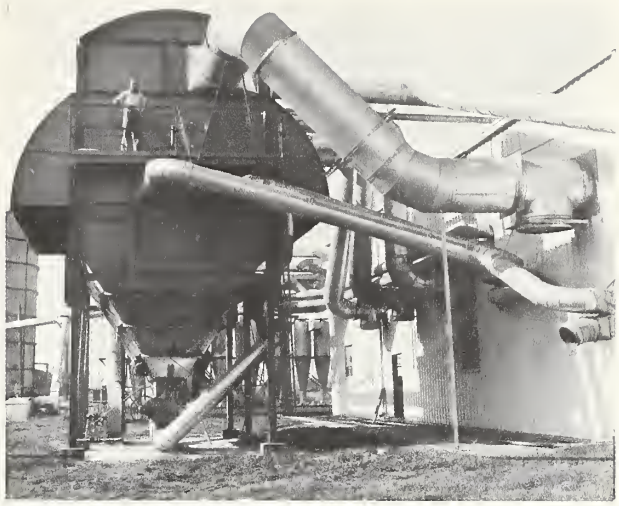

FIGURE 8.—Commercial-size experimental trash-collecting system.

TABLE 2.—*Results of using mesh-screen filter medium with prototype unifilter*

Replication	Seed cotton at wagon[1]		Ginning rate (bales/h)	Total air volume[2] (stdft^3/min)	Total trash input[3] (lb/h)	Dust emission[4] (lb/h)	Filter efficiency[5] (pct)	Enclosure static pressure[6] (inH_2O)
	Moisture (pct)	Foreign matter (pct)						
1	9.7	5.1	4.3	16,939	342.58	11.84	96.54	0.07
2	11.8	6.8	3.5	18,079	413.93	18.47	95.54	.16
3	12.3	6.7	3.3	20,299	493.27	17.76	96.40	.10
Average	11.3	6.2	3.7	18,439	416.59	16.02	96.16	.11
1	9.5	3.8	7.2	17,214	564.56	12.56	97.78	0.14
2	10.3	6.7	5.7	18,598	669.50	16.03	97.61	.21
3	9.4	4.1	8.6	17,292	623.98	15.73	97.48	.11
Average	9.8	4.9	7.2	17,701	619.35	14.77	97.62	.15
1	11.7	6.6	5.8	21,823	739.09	26.22	96.45	0.16
2	9.5	5.3	7.0	19,785	728.25	22.97	96.85	.26
3	11.9	5.6	6.8	22,189	717.36	28.11	96.08	.13
Average	10.0	5.8	6.5	21,265	728.23	25.77	96.46	.18

[1] Determined by standard moisture and fractionation tests.
[2] Air volume filtered by unit corrected to standard cubic feet.
[3] Total of material collected by filter media and particulate matter escaping unit.
[4] Particulate matter escaping unit as determined from dust concentration in micrograms per cubic meter and total air volume handled.
[5] Ratio of material collected by unit to total trash input to unit.
[6] Static pressure as measured with an inclined manometer.

was deflected down into the hopper to protect the filter.

All of the air discharged from the gin system was piped into the enclosure to be cleaned. A total of 111,000 cubic feet per minute of contaminated air was cleaned through 500 square feet of filter, which resulted in a face velocity of 222 feet per minute at the surface of the filter. The light material and dust was collected by the filter and was doffed by 10 nozzles (having inlet openings 0.88 by 24 inches wide) with an airflow rate of 700 cubic feet per minute per nozzle. The suction air for the nozzles was furnished by a No. 50 fan, which also handled the trash from the hopper.

The system was in operation throughout the 1973 season, during the ginning of over 7,000 bales of machine-picked cotton, but no insurmountable problems were encountered. The volume of lint waste handled by the nozzles was a problem at the beginning of the season because of the lint catching on portions of the nozzles. However, modification of the nozzles eliminated much of this problem. The flexible plastic hoses between the nozzles and the suction manifold were excessively worn during the first 1,000 bales of operation, but these hoses were replaced with rubber-lined hose. It was necessary to clean out the nozzles and remove the trash buildup on the nozzle supports every 200 to 300 bales of operation, a job accomplished by two men in about 10 minutes. The location of the nozzle supports and suction manifold caused lint waste to build up on these parts. The modifications necessary to correct these conditions were not possible during the fast-moving ginning season.

Several fires occurred during the ginning season, and at least four major fires went through the experimental unit to the trash pile. These fires caused no damage to the enclosure and only minor damage to the filter medium, but the damage was not bad enough to require replacement of any of the components of the system.

Design Modifications

Two modifications were made to the experimental filter system after the 1973 ginning season.

TABLE 3.—*Data for selecting proper size unifilter for commercial ginning systems*[1]

Drum diameter (ft)	Media area (ft^2)	No. nozzles	Air volume (ft^3/min) at face velocity (ft/min) of—			
			100	150	200	250
4	50.4	2	5,040	7,560	10,080	12,600
4	75.6	3	7,560	11,340	15,120	18,900
5	62.8	2	6,280	9,420	12,560	15,700
5	94.2	3	9,420	14,130	18,840	23,550
5	125.6	4	12,560	18,840	25,120	31,400
6	75.2	2	7,520	11,280	15,040	18,800
6	112.8	3	11,280	16,920	22,560	28,200
6	150.4	4	15,040	22,560	30,080	37,600
7	88.0	2	8,800	13,200	17,600	22,000
7	132.0	3	13,200	19,800	26,400	33,000
7	176.0	4	17,600	26,400	35,200	44,000
7	220.0	5	22,000	33,000	44,000	55,000
8	150.0	3	15,000	22,500	30,000	37,500
8	200.0	4	20,000	30,000	40,000	50,000
8	250.0	5	25,000	37,500	50,000	62,500
8	300.0	6	30,000	45,000	60,000	75,000
9	169.8	3	16,980	25,470	33,960	42,450
9	226.4	4	22,640	33,960	45,280	56,600
9	283.0	5	28,300	42,450	56,600	70,750
9	339.6	6	33,960	50,940	67,920	84,900
10	188.4	3	18,840	28,260	37,680	47,100
10	251.2	4	25,120	37,680	50,240	62,800
10	314.0	5	31,400	47,100	62,800	78,500
10	376.8	6	37,680	56,520	75,360	94,200

[1] Based on total air volume of the cotton ginning system.

1. The vacuum nozzles were moved from the horizontal plane location to a location 20° below the horizontal and toward the underside of the filter drums and were mounted on the air manifold, rather than the original beam support. This modification made the nozzles more accessible and reduced the trash buildup that accumulated on the nozzle supports of the initial design.

2. The vacuum nozzles were located and adjusted so that the inlet opening of each nozzle was tilted upward approximately 15° from the point of tangency and counter to the direction of rotation of the filter drum. This adjustment caused the lower lip of each nozzle to make contact with the filter, whereas the upper lip of each nozzle was approximately one-eighth of an inch from the surface of the filter. These adjustments caused the trash batt to enter the nozzle, which eliminated the possibility of chokage that would have caused an increase in the back pressure on the ginning system.

The overall operation was exceptionally good for an experimental unit, and the collection efficiency was judged to be higher than that of the prototype unit tested in 1972. If the economics of this system is favorable, it will provide an additional system of abatement equipment from which to choose in meeting the air-pollution standards.

Size Selection

The proper size unifilter system for a gin plant is determined by the volume of air to be filtered and the face velocity at the filter. The collection efficiency increases as the face velocity at the filter surface decreases. A face velocity of 150 to 250 feet per minute is satisfactory for cotton gins. Table 3 gives the air volume of the system at various face velocities and the required filter-drum sizes. The enclosure should be designed to incorporate the size and number of drums as dictated by the total air volume handled by the cotton-ginning system.

The overall goal of the laboratory was to develop a unit waste-collecting system for cotton gins that would meet the strict standards set by the various State air-pollution control boards. Present research data indicate that such technology is now available. The economics of such a system will dictate whether or not it will be commercially used by the ginning industry.

CONCLUSIONS

The unifilter trash-collection concept has proved to be an alternate means of abating air pollutants from cotton-ginning systems. The collection efficiency of this system is comparable to, if not higher than, the presently accepted collection system for cotton gins. At present, the unifilter system is being produced by gin-equipment manufacturers for collecting all cotton-gin waste materials. Gin manufacturers are also producing modified versions of this system for collecting the lighter materials emitted from cotton condenser systems.

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